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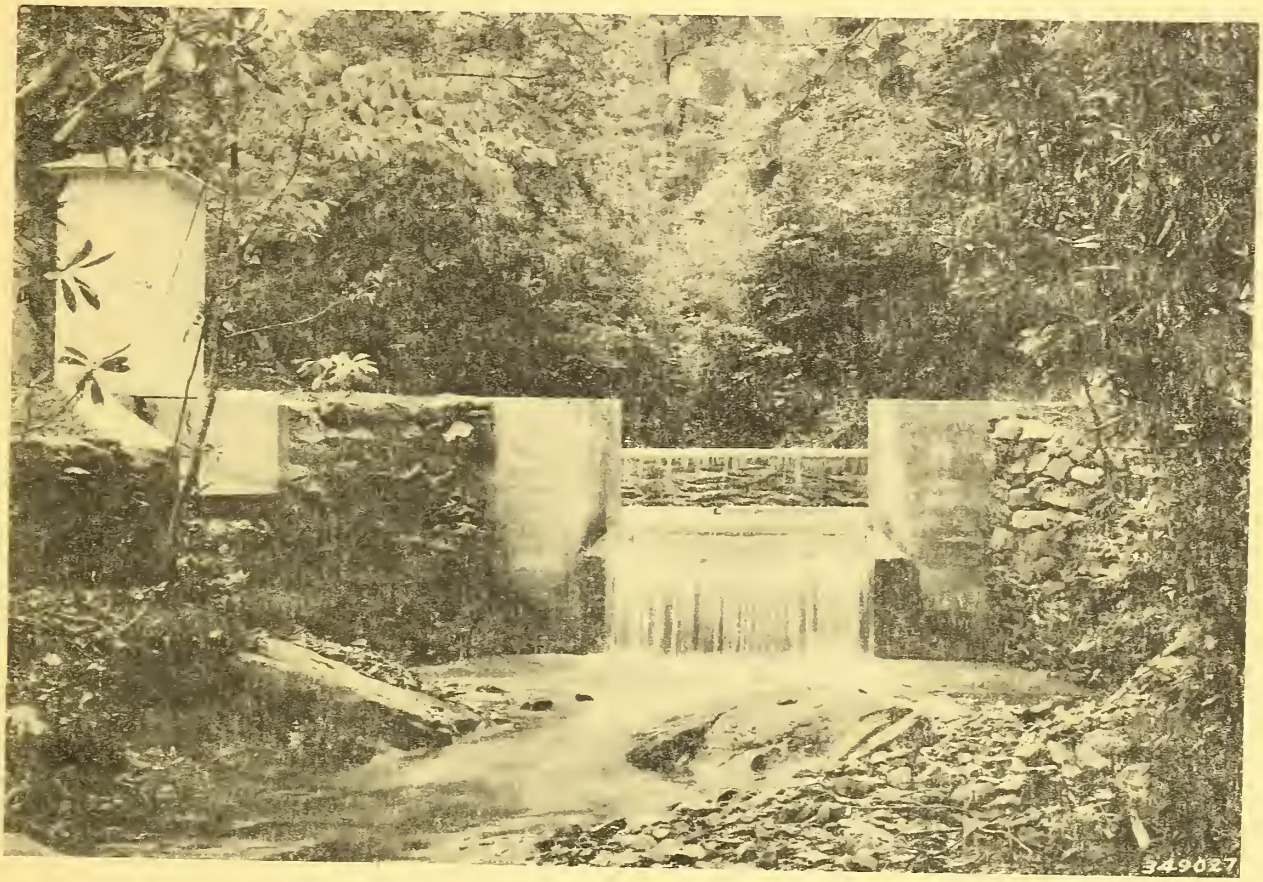
WATERSHED MANAGEMENT RESEARCH COWEETA EXPERIMENTAL FOREST

MACON COUNTY, NORTH CAROLINA
MAY 1948



FOREST SERVICE

U. S. Department of Agriculture

Southeastern Forest Experiment Station
Asheville, North Carolina

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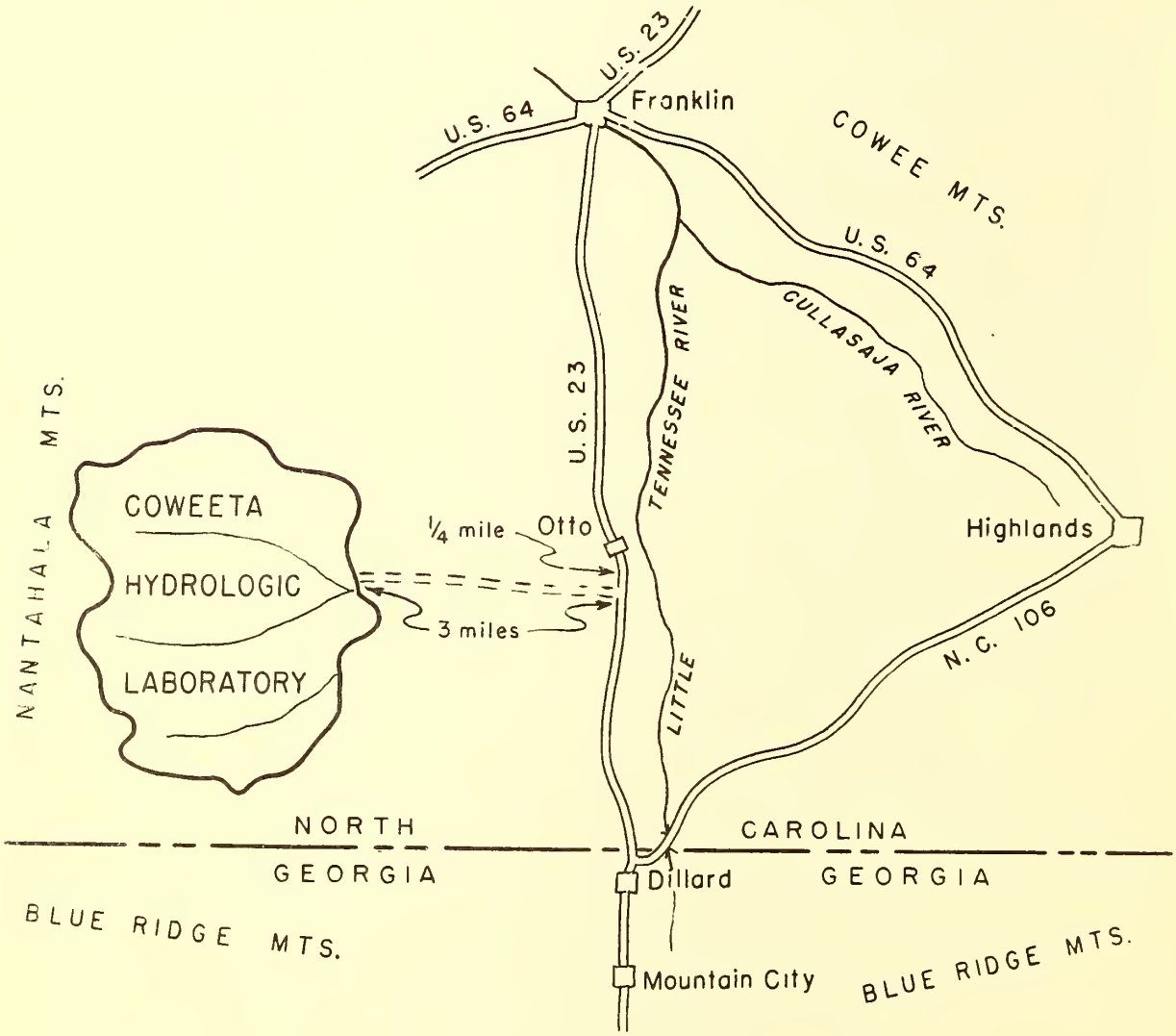
The Coweeta Experimental Forest, a 5400-acre outdoor laboratory for watershed management research, is located about 80 miles southwest of Asheville, North Carolina, in the Nantahala Mountains. It is reached by turning west on a gravel road which meets U. S. Highway 23 at a point 11 miles south of Franklin, N. C., or 9 miles north of Mountain City, Ga. The intersection is marked by a sign, and from there it is 3 miles to headquarters.



THE COWEETA EXPERIMENTAL FOREST

Water is one of the least understood of all the natural resources basic to our national economy. Because water resources are definitely related to climate, many have believed man could change them no more than he could change the weather. This is not entirely true, for within any one locality water resources are controlled by other factors than climate alone. The most important of these are vegetation and the physical condition of the soil. Through his use of the land, man can and does exert a very significant influence on both vegetation and soil. In so doing, he also modifies the water resource, but the nature and extent of this modification has been a subject of much speculation and uncertainty.

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Those who are most familiar with natural areas and who have observed stream conditions in the undisturbed forest have a strong conviction that good forests, good soils, and good water go hand in hand. It is reasonable to believe that through the centuries there has developed a harmonious adjustment of physical forces that relate vegetation, soil, and water. We know, however, that this natural adjustment appears to be in a delicate balance. It is impossible to disturb the forest without in some way disturbing this natural adjustment. However, as we come to better understand the physical forces that must be kept in balance, we will be better able to develop land management practices which will permit us to utilize all forest resources without jeopardizing any one resource at the expense of another.

The chief reason why we know so little about water as compared to other important products of the forest is because of the lack of observational data. Because of this lack it has been impossible in the past to establish a scientific basis for managing water as a natural resource. The Coweeta Forest has been developed in recognition of this need for basic scientific data. Here the Forest Service through fundamental hydrologic research is developing practical methods of forest land management for maximum timber, forage, and water production consistent with region-wide interest in flood control and the industrial, municipal, and recreational use of water.

DESCRIPTION

Several factors combine to make the Coweeta area particularly suitable for fundamental hydrologic research. Rainfall is high and uniformly distributed throughout the year. With an average of 100 storms a year, an abundance of data can be obtained in a short span of years. Most of the precipitation occurs as rain, and there is little snow to complicate the problem. The hardwood forest of the area is typical of much of the eastern United States. Research findings here can be widely applied elsewhere. Consequently, research in water resource management on the Coweeta Experimental Forest has national as well as local significance.

Physiography and Soils

Elevations range from 2200 feet at the administrative area to over 5200 feet on the western boundary. Slopes are steep, and sharp-crested ridges form boundaries for the experimental watersheds. The mountains of the Blue Ridge region have never been subject to glaciation but have been subject to great geologic erosion and weathering. For most of the Blue Ridge and for the entire Experimental Forest the underlying rock is the Archean Carolina gneiss and schist. Thickness of this formation is enormous and was greatly increased by folding. As a result of this complex folding and the absence of open faults or fractures, there is little likelihood of continuous channels through the rock that would allow subterranean escape of water.

The parent rocks weather to form a deep soil mantle, with bare rock outcrops occurring only on steep slopes at high elevation. The slopes are covered with a residual soil mantle from 2 to 4 feet in depth, usually underlain by several feet of decomposed rock. Most of these slope soils are in the Porters Soil Series. At the foot of the slopes and in coves or benches there is an accumulation of soil from the slopes. These colluvial soils are from 4 to 8 feet in depth and are classified as in the Tusquitee Series.

Climate

Moderate temperatures and abundant rainfall characterize the climate at Coweeta. The mean annual temperature is 55°F. and the normal frost-free season extends from April 17 to October 23. During the growing season the temperature averages 65°. Temperatures above 90° are rare and summer nights are cool, with minimum temperatures averaging 58°. The average temperature of December, January, and February is 39° and periods of cold weather with temperatures less than 20° are short in duration.

Rainfall is well distributed throughout the year. For the past 10 years, precipitation has averaged 3.2 inches in October, the driest month, and 7.2 inches in March, the wettest month. The average annual amount over the Experimental Forest is 77 inches. The greatest amount of rainfall is received in the southwest portion of the forest and the least in the northeast corner. The difference between these two zones is about 20 inches a year.

Vegetation

Hardwood trees are the dominant vegetation, with pine present only on old fields or on ridge tops at lower elevations. Sixty percent of the area was logged before 1923 and is now in second growth forest, while the remainder is old growth. Previous to the outbreak of the chestnut blight, chestnut was the dominant species, forming over 50 percent of the stand. The forest is typically three storied, with large trees forming the upper layer, small trees a second layer, and either shrubs or herbs covering the ground. The percent of area occupied by different forest types is:

Regional Forest Type	Percent of Coweeta Area
Oak-hickory	77
Cove hardwoods	15
Pitch pine-hardwoods	5
Northern hardwoods	3

A partial list of tree species includes: black oak, scarlet oak, chestnut oak, white oak, eastern red oak, yellow-poplar, cucumber, Fraser magnolia, white ash, basswood, red maple, black cherry, black birch, various hickories, black gum, hemlock, and pitch pine.

Land Use History

The area near Franklin, N. C., was the heart of the Cherokee Indian Nation and many of their camp sites have been found on the Experimental Forest, but there is no evidence of a permanent Indian settlement here. The first white settler built his cabin at the present administrative site in 1848, and finally, homes were built at perhaps 10 other locations. The total area cleared for agriculture was less than 200 acres, mostly for corn and other grains. Woodland grazing, which furnished most of the settlers' livelihood, undoubtedly affected the forest. Estimates are that at one time 1500 head of sheep, 3500 hogs, 600 cattle, and 80 horses and mules were on the area. To favor grazing, the area was burned over annually, a practice said to have been started by the Indians.

The settlers were moved from the area in 1902 when it was purchased by a large land company which later sold it to operating lumber companies. However, grazing and burning continued after this purchase.

Logging began in 1909, with various small cutting operations continuing to 1918. At this time the land was sold to the Forest Service with the timber rights reserved. The reserved timber was cut off between 1918 and 1923. By agreement with the Forest Service, no trees were cut that were smaller than 15 inches on the stump. The volume removed was about 8 million board feet.

No large fires have occurred since Forest Service ownership, and grazing use was gradually reduced and finally stopped completely with the establishment of the experimental forest.

RESEARCH PROGRAM

The objectives of forest influences research on the Coweeta Experimental Forest, with some of the problems to be solved, are listed below.

I. To establish fundamental forest-streamflow relationships.

   a. What are stream-flow conditions from natural forested watersheds?

   b. How are water resources influenced by forests and forestry practices?

   c. How can water resources be managed to obtain maximum yields and uniformity of flow, particularly for municipal and industrial watersheds?

   d. How can management for maximum water yields and uniform flows be integrated with other uses of forest land?

II. To furnish coefficients of runoff, infiltration and water storage for different land management practices.

   a What is the effect of forests on local and general floods?

   b What is the effect of land use practices, such as woodland grazing, logging, mountain farming, and forest fires on water resources?

   c How can forestry practices best serve in the rehabilitation and restoration of depleted and abandoned land?

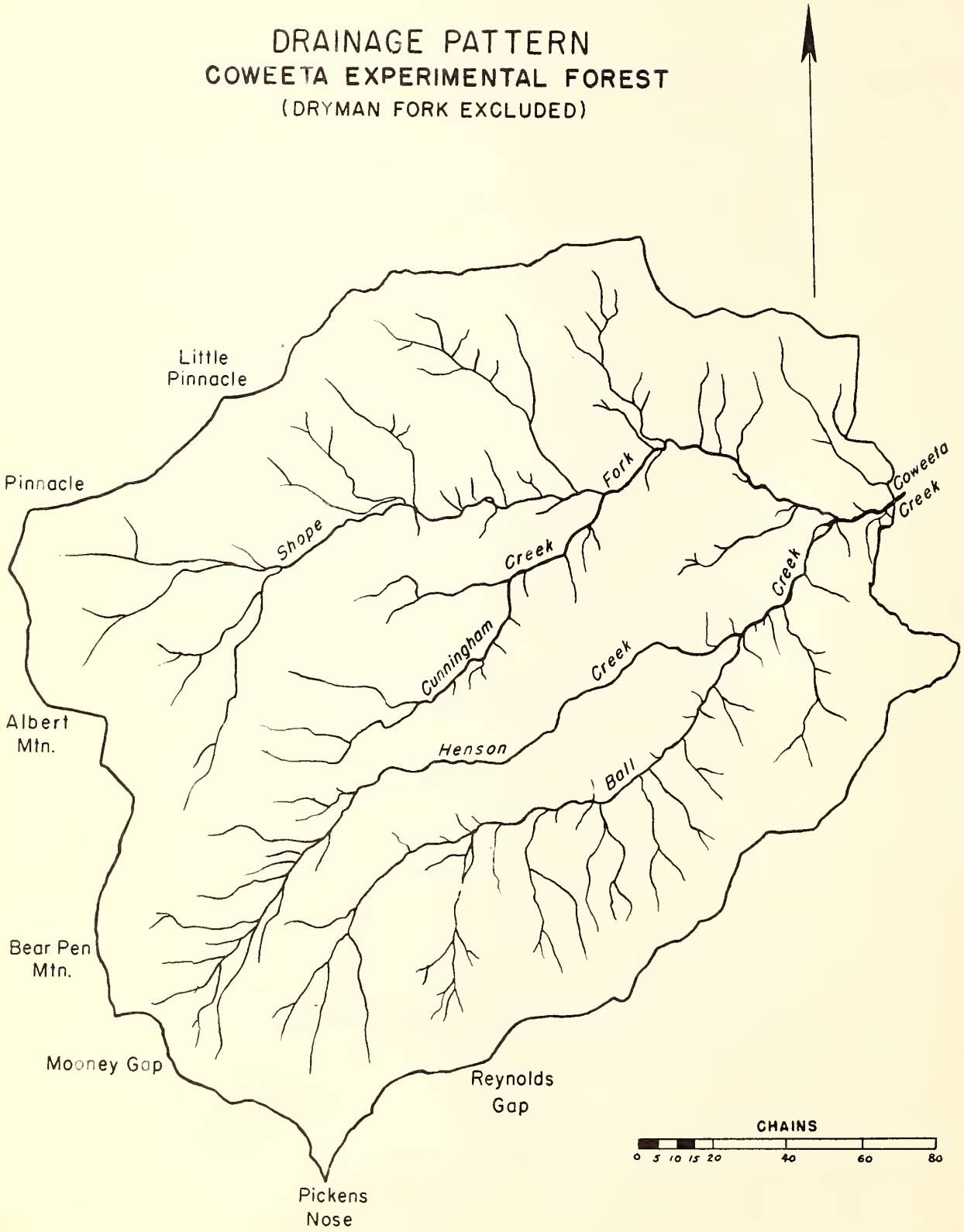
III. To discover relationship between forests and climate.

   a. How do forests influence micro-climate?

   b. Can forest cover be managed to improve local climates?

IV. To work out feasible and practical soil stabilization practices for logging roads, highway roadbanks, stream banks, and reservoir shore lines.

Work to date has been directed mainly toward the first two of these objectives.


DRAINAGE PATTERN
COWEETA EXPERIMENTAL FOREST
(DRYMAN FORK EXCLUDED)
Little Pinnacle
Pinnacle
Albert Mtn.
Bear Pen Mtn.
Mooney Gap
Pickens Nose
Reynolds Gap
Shope Creek
Fork
Coweeta Creek
Cunningham Creek
Henson Creek
Ball Creek
CHAINS
0 5 10 15 20 40 60 80

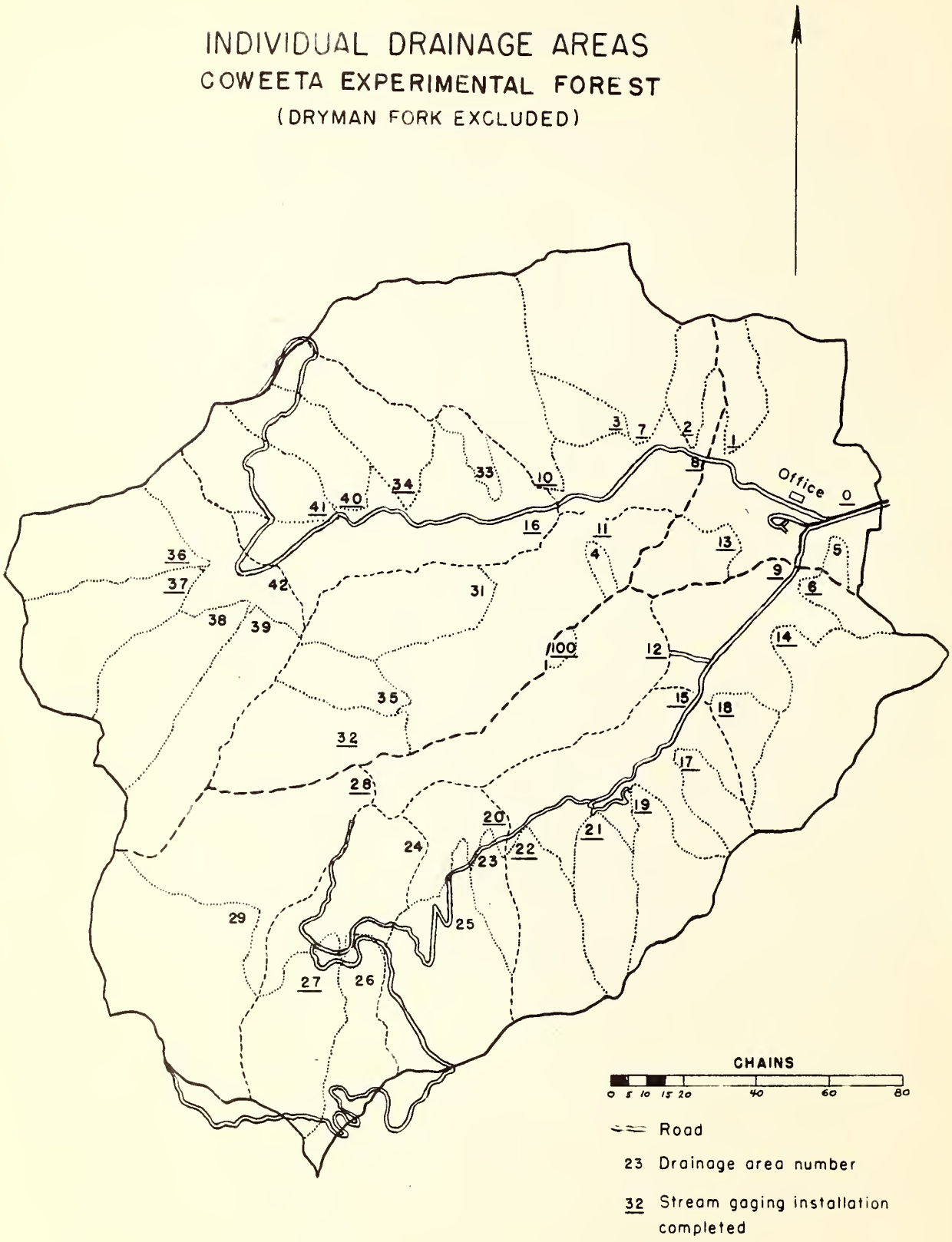
EXPERIMENTAL PROCEDURE

Work began in 1933 with an inventory of the area. Topographic and forest type maps were prepared and, in general, the characteristics of the area were established. The next step was to learn how water resources were controlled naturally. To measure rainfall, 75 rain gages were distributed throughout the area along 30 miles of foot trails. These gages are read after each storm. Rates of rainfall are measured by 13 recording rain gages which show on a chart the amount of rain at any time. At the foot of each of 30 watersheds a concrete dam has been built to cut off all water flow and direct it through a measuring section. Rates of runoff are continuously recorded at these weirs by instruments. Twenty-two ground-water observation wells are also equipped with water-level recorders to measure water-table fluctuations. Climatic information has been obtained from 14 weather stations located to sample conditions for different elevations and aspects.

Experimental procedure for each watershed includes a period of observation for stream flow and precipitation; also a study of existing vegetation and soil conditions. From these records we are able to compare rainfall and runoff for each drainage area. The period of standardization requires about 5 years, during which stream flow and other essential water cycle characteristics of the watershed become known. Changes in the vegetation cover are then carried out under carefully controlled experimental procedures, while the records continue to be kept. By this experimental plan, accounts are kept of the continuous water economy of the experimental watershed both before and after changes are made in the vegetation cover. From these accounts it is possible to determine the effects of land use changes on the yield and quality of water from each experimental watershed. Changes in turbidity and water quality brought about by land use are also being studied.

Differences in stream discharge before and after changes have been made on the watershed are compared statistically on the basis of runoff variables. In addition, it has been found possible to use a second watershed as a control to check year-by-year climatological differences during the entire period of observation.

INDIVIDUAL DRAINAGE AREAS
COWEETA EXPERIMENTAL FOREST
(DRYMAN FORK EXCLUDED)



COWEETA STREAM GAGING INSTALLATIONS

Combination or Multiple Watersheds

No.	Acreage	Elevations Max. (Ft.)	Elevations Min. (Ft.)	Control	First Record	Flow Max. (C.s.m.)	Flow Min. (C.s.m.)
0	4000	5250	2200	Control Section			
8	1877	5250	2292	12-ft. Cippolletti	Oct. 6, 1934	59	0.65
9	1788	5097	2253	12-ft. Cippolletti	Oct. 12, 1934	84	0.49
11	440	4056	2407	5-ft. Rectangle	Mar. 5, 1936	52	0.96
12	501	5097	2412	6-ft. Cippolletti	Mar. 17, 1936	101	0.56
15	940	4887	2352	8-ft. Cippolletti	Dec. 21, 1936	114	0.48
16	943	5250	2423	6-ft. Rectangle	June 4, 1936	86	0.13
20	511	5097	2423	6-ft. Rectangle	July 30, 1937	114	0.51

Unit Watersheds

1	39	3241	2315	90° V-notch	June 13, 1934	86	0.26
2	31	3314	2340	90° V-notch	June 22, 1934	80	0.12
3	23	3055	2425	CIA-Deep Notch	July 5, 1934	397	0.26
6	22	2955	2282	90° V-notch	July 10, 1934	155	0.32
7	145	3510	2370	CIA-Deep Notch	July 31, 1934	42	0.59
10	212	3801	2436	120° V-notch	Mar. 7, 1936	35	0.31
13	40	2965	2349	120° V-notch	Mar. 12, 1936	88	0.50
14	152	3125	2318	120° V-notch	May 26, 1936	113	0.51
17	33	3381	2422	90° V-notch	June 6, 1936	124	0.40
18	31	3258	2382	120° V-notch	June 3, 1936	114	0.25
19	69	3650	2550	120° V-notch	May 17, 1941	62	0.81
21	59	3850	2720	120° V-notch	July 22, 1938	113	0.53
22	88	4089	2780	120° V-notch	Feb. 18, 1937	160	0.36
27	100	4770	3540	120° V-notch	Nov. 2, 1946	109	0.37
28	350	5097	3162	6-ft. Rectangle	May 24, 1937	128	0.64
32	102	4050	3050	120° V-notch	Oct. 25, 1941	49	0.91
34	76	3900	2775	CIA-Deep Notch	Oct. 13, 1938	35	0.76
36	110	5050	3440	120° V-notch	Apr. 29, 1943	84	0.60
37	100	5250	3440	120° V-notch	Apr. 15, 1942	170	0.43
40	58	4000	2860	CIA-Deep Notch	Dec. 4, 1938	32	0.46
41	71	4260	2930	120° V-notch	Aug. 23, 1940	61	0.67
100	7	3185	3025	90° V-notch	Mar. 14, 1938	40	0.06
I-1	200	4900	3650	2-ft. San Dimas	Dec. 5, 1947		

A STUDY OF THE EFFECTS OF STEEP LAND AGRICULTURE - AREA NO. 3

Purpose

Thousands of acres of steep forest land within the Blue Ridge have been cleared for use as cropland or pasture. It is known that great skill and care are needed to farm such land successfully, and that much of it should not be farmed at all. However, each year population pressure forces the clearing of new land and the reclearing of old. To evaluate the effect of this practice upon stream flow and sedimentation, more precise information is needed than has been available. For this reason, one of the Coweeta watersheds, after being calibrated in forest cover, has been cleared and a portion planted in corn and the remainder used as pasture. As nearly as possible the land is handled as it would be if a mountain family lived near the stream gage and tended the area to make their livelihood.

Description of Area

Size - 22.8 acres.

Elevation - 2245 at stream gage to 3124 at top.

Stream gaging - First record July 7, 1934. 90° V-notch replaced CIA control on December 20, 1939.

Ground-water wells - Four observation wells were dug in 1941. Two of these are equipped with recorders.

Meteorological station - Air and soil temperatures were measured from March 1940 to October 1944. For comparison another station was located in the adjacent woodland of Area 7.

Debris basin for sediment measurement installed August 28, 1941.

Land Use History and Vegetation

About 10 acres of this watershed were cleared for cultivation and pasture in 1857 and abandoned in 1887. Forest cover was re-established by 1900. The dominant type was black oak and scarlet oak but considerable yellow-poplar was also present. By 1940 the dominant trees of the old clearing were 16 to 24 inches in diameter.

Clearing Land for Agriculture. Drainage Area No. 3.

Preparation for experimental watershed study of the use of steep forest land for cultivation and grazing.

Clearing

All vegetation on the entire watershed was cut between November 1939 and May 1940. On the lower portion, the stumps less than 16 inches were pulled and brush was piled and burned around the larger stumps. On the extreme upper portions, the trees were cut and the resulting slash was scattered over the ground to form a mulch.

Cultivation

An area of 5.6 acres was fenced and plowed in 1941. Because of roots, a bull tongue or single foot plow was used. Hickory King corn was planted and no fertilizer used. The yield was 132-1/2 bushels, or 23.6 bushels per acre.

1942 Plowing was again done with a single foot plow, and Hickory King corn planted. No soil fertilizers were used. Because of a wet summer, corn was worked only once and windstorms blew down much of the corn. The yield was 84 bushels, or 15.3 bushels per acre.

1943 Plowed with single foot and planted to Golden Prolific corn. Field erosion occurred for the first time in this season. This was due in part to reduction in organic matter in the soil and also to a series of very intense thunderstorms in June and July.

1944-45 No corn planted. Area grew up to natural weeds, with ragwood and cinquefoil most abundant and blackberries along the fence. Many seedlings and sprouts of yellow-poplar and locust became established.

1946 Plowed with single foot and planted to Hybrid U. S. 13 corn. The harvest was 65 bushels, or 11.6 bushels per acre. This corn was poorly adapted to the situation, and deer and ground hogs also took a heavy toll.

1947 Plowed lower slopes with a hillside turning plow and upper slopes with single foot. Fertilizer used for first time. The total amount used was 800 lbs. of 4-10-4. Hickory King was planted and the yield was 90 bushels, or 16 bushels per acre.

Grazing

There are 17 acres outside the cornfield, about 5 acres of which are too rough or brushy for cattle. The remaining 12 acres are suited to pasture, particularly the 9 acres below the gage trail.

1941 No grazing.

1942 One hundred pounds of pasture seed were sown on 12 acres. Competition from trees and sumac prevented a catch of grass. However, about 20 percent of the area below the gage trail was stocked with native or planted grasses. Cattle were alternated between this pasture and the adjacent woods (Area 7). In all there were 336 animal days of grazing on Area 3 (7 cattle for 48 days). Herbaceous vegetation was 80 percent utilized by September 21, and evidences of trampling were conspicuous.

1943 Eight animals were grazed for 67 days on Area 3. The sprouts below the gage trail were cut back in August. The lower portion below the weather station was picked almost clean but sprout growth on the extreme upper slopes was untouched.

1944 A drift fence was built just above the weather station to better control grazing and prevent concentration on the lower portion. Cattle were alternated between the two parts. Five head of cattle were kept continuously on the area from May 8 to September 22 for a total of 685 animal days. Nearly all available forage was used and in the lower portion the soil surface was severely trampled and compacted. The remaining perennial herbaceous vegetation was considerably reduced by frost heaving the following winter.

The cattle made an average daily gain of 0.98 lbs. per head. The greatest gains occurred in May and June and averaged 1.56 lbs. per day.

1945 Cattle were alternated between Areas 3 and 7, as was the case in 1942-43. The cattle grazed the Area 3 for a total of 631 animal days.

1946 The fence between Areas 3 and 7 was opened and cattle were alternated between the upper pasture of Area 3 and all of Area 7, and the lower part of Area 3 and all of Area 7. There was a total of 1377 days of grazing on both areas. Observation indicated that two-thirds of the use was on Area 3, and 85 percent of the food came from that area.

Cultivation of Steep Slopes. Drainage Area No. 3.

Eroded top soil from cornfield is deposited by stream in debris basin where it is measured.

1947 Three head of cattle were alternated between upper and lower portions of Area 3 for a total of 588 days of grazing. The average daily gain was 0.54 lb. Sprouts were cut back in early May on the lower pasture.

Peak Runoff Rates

The maximum rate of runoff measured before clearing was 110 c.s.m., as a result of a rain of 4.67 inches in November 1938. The maximum intensity of the rain was 2.12 inches per hour.

Since clearing, a peak of 398 c.s.m. was recorded in July 1943, as a result of 1.65 inches of rain at an intensity of 4.00 inches per hour. This type of rain did not cause peaks of over 54 c.s.m. before clearing. For rains of low intensity, there has been little change in runoff characteristics but for thunderstorm rains a big change has taken place. A comparison of intense thunderstorms before and after clearing shows this well.

Date of Storm	Max. 10 Min. Intensity (Inches per hour)	Total Rain (Inches)	Peak Runoff (C.s.m.)
Aug. 22, 1934	4.64	1.91	48
July 12, 1936	5.46	2.03	43
Sept.20, 1930	3.72	1.82	54
June 13, 1943	6.00	1.34	128
June 14, 1943	4.20	0.86	88
July 30, 1943	4.00	1.72	398

Sediment Movement

Before clearing, the rate of sediment movement based on accumulation in the weir pond was 9.4 lbs. per day. After clearing, the following rates were measured in the debris basin. All weights are on the day basis.

Aug. 28, 1941 to May 4, 1943	22.7 lbs. per day
May 4, 1943 to Sept. 8, 1943	767.6 lbs. per day
Sept. 8, 1943 to April 16, 1946	46.3 lbs. per day
April 16, 1946 to April 2, 1947	38.5 lbs. per day

Future Plans

The same treatment will be continued until yields from the land are so low that cultivation would not be profitable. At this time a program of conservation farming and rehabilitation will be begun to learn effective methods and the length of time required to restore water values.

A STUDY OF THE EFFECT OF WOODLAND GRAZING - AREA NO. 7

Purpose

In the early days of settlement, livestock ranging in the woods was the main support of the people, but the advent of fence laws and decreased economic returns have diminished the importance of this open ranging as a means of support. Now, however, on the average mountain farm, the woodland is fenced in with the pasture and receives very heavy use. The aggregate area of grazed woodland is great. For example, in Macon County it is estimated that over 50 percent of the land on farms is in woods and 80 percent of this is grazed. When it is realized that the estimated area of grazed woodland is 20 percent of the land area of the county, it is easy to realize the need for better understanding of the effects of this practice on water resources.

The intention of the experiment is deliberately to overgraze and trample the watershed to make it comparable with the typical farm wood lot. Before grazing was begun, seven years of record were collected, with the watershed in its natural condition.

Description of Area

Size - 145 acres.

Elevation - 2370 at stream gage to 3510 at summit.

Stream gaging - 90° V-notch installed July 31, 1934. On November 1, 1939, this was replaced by CIA control.

Ground-water wells - A recording well in the lower portion has been in operation since June 18, 1940.

Vegetation

About 80 percent of this watershed is in the oak-hickory type, 14 percent pitch pine-hardwoods, and 6 percent in cove hardwoods. Previous to grazing, the cove hardwood site had a dense herbaceous cover which included many native legumes. About half of the oak-hickory type had a ground cover of palatable species, while the rest had a dense cover of either laurel or buckberries, as does the pitch pine-hardwoods site.

Treatment Record

1940 One hundred and thirty-three acres were fenced, and within this area 17 fenced exclosures of 0.4 acre were established. An equal number of unfenced sample plots were marked by corner stakes to serve for comparison. The total area available to cattle is 126 acres. Detailed analysis of vegetation was made on quadrats within the sample plots.

1941 An average of 11 head of cattle were grazed for the 104-day period, May 17 to August 28. The animals did well until August when they began to lose considerable weight. By the end of the period about 90 percent of the palatable forage was utilized. About 60 percent of the food came from browse and the remainder from herbaceous species.

Some approximate species utilizations are as follows. Percentages refer to the amount of material within reach that was actually eaten. Trees up to 4 inches in diameter were ridden down and the tops eaten.

	Percent		Percent
Yellow-poplar	98	Sourwood	90
Blackberry	98	Summer grape	90
Virginia Creeper	98	Ferns	90
Annuals (all kinds)	98	Black birch	80
Grasses (all kinds)	98	Sassafras	65
Smilax	95	Dogwood	50
Black locust	95	Chestnut	20
Ash	90	Chestnut oak	10
Witch hazel	90	Scarlet oak	1

1942 Cattle were alternated between this watershed and the cleared watershed adjacent. A total of 546 animal days were spent on this area in alternate 2-week periods between May 18 and September 7.

1943 Cattle again alternated between the two areas. Cattle used the area 312 animal days between June 2 and August 8.

1944 Between 5 and 6 animals were kept continuously on the area. The animal days of grazing were 753 between May 12 and September 22. Supplemental feeding of 2-3/4 pounds of corn powder with 1/4 pound of cotton seed meal began on June 1. This furnished only a portion of the animals' needs but kept them in good condition. Grazing use was heavy over the entire area. The average daily gain was 0.53 lb. per head.

1945 Animals alternated between Areas 3 and 7, with 651 animal days between April 16 and August 24 on Area 7.

1946 Cattle allowed to move at will between Area 3 and Area 7. Use on Area 7 light except along fence line. Estimated use was 450 days on this area.

1947 Four cattle were put on May 26 and one more July 7. They remained until September 29 for a total of 565 animal days. They were fed a supplement identical with that in 1944. Average daily gain was 0.6 lb. per day.

Results

Stream-flow observations obtained since treatment began have not yet been evaluated. Soil sampling at the end of the first year of grazing showed that macro-pore space in the upper 4 inches of soil was reduced 10 percent. About 40 percent of the area is now heavily trampled, and the general appearance of the entire area is becoming typical of grazed farm wood lots.

Future Plans

Grazing use will be continued with supplementary feeding. Detailed soil and vegetation studies will be made to compare character of fenced exclosures with unfenced plots. Stream-flow records will be analyzed to measure changes caused by treatment. Eventually, rate of recovery after grazing will be determined.

A STUDY OF THE EFFECT OF ORDINARY LOGGING PRACTICES ON WATER - AREA NO. 10

Purpose

The job of getting logs from the tree stump to the sawmill is a difficult and laborious one. It is necessary to skid the logs to a point where they can be loaded on trucks. To get trucks within reasonable distance, woods roads have to be built. In building and using these skid and truck roads, large amounts of soil are disturbed and conditions are created which can result in a great deal of erosion. Ordinarily, little thought is given to the possible consequences of this disturbance upon water. However, it is a common observation that logging activity muddies the streams, and fishermen know that trout fishing is poor from logged areas until several years' storms wash away the accumulated sediment in the stream.

The purpose of this experiment was to obtain for the first time a measure of the effect of logging upon water values and particularly the quality of the water, in short, to measure how muddy the water became on account of logging activity, and what effect runoff from the areas of disturbed soil had upon the stream hydrograph.

Description of Area

Size - 212 acres.

Elevation - 2436 to 3801 feet.

Stream gaging - 120° V-notch weir completed in March 1936.

Meteorological Station - Records of air and soil temperature, wind movement, humidity and evaporation were taken within the area from October 1936 to July 1939.

Land Use History and Vegetation

About 1918, 45 percent of the area was cut over, and the remainder was old-growth timber when this experiment began. Only one acre at the lower portion of the watershed had ever been cleared for agriculture. Oak-hickory was the dominant forest type, occupying

82 percent of the area. Pitch pine was on 12 percent and cove hardwoods on 6 percent. About 200 M. board feet of merchantable green timber was estimated to be present in 1942. In addition, there were 80 M. board feet of chestnut logs and an estimated 1300 cords of chestnut extract wood.

Treatment Record

1942-43 A timber sale was made in 1942. Logging was in progress from May 11 to September 15 and from November 30 to March 10, 1943. The sale was then closed, mainly because of difficulty in obtaining labor during the war period. The cutting should be classed as a light selection, as only 530 logs with a scale of 86 M. were taken.

Animal skidding was used and no truck road was built into the watershed. Logs were skidded an average distance of 1/2 mile to a landing near the weir.

A silt trap was built to measure the sediment eroded from a section of this trail 440 feet in length on a 30 percent slope. Between June 25 and August 20, 1942, 250 cubic feet of soil were caught. This rate of erosion amounts to 100 cubic yards per mile of road.

1945 No further logging activity took place until January 5, 1945. Washing continued on the skid road but at a lower rate than during operation. No measurements were taken because of shortage of personnel caused by war. In January 1945, the chestnut extract wood was sold and 155 cords were cut and skidded, using the old logging road.

1946-47 In January 1946, 0.8 mile of truck road was bulldozed into the area by the contractor to facilitate operation. He was allowed to build it just as he would on other areas and picked his own location. In January 1947, an additional 0.7 mile of road was built and green timber cutting began again. An extension of 0.8 mile was made to the road in November 1947 and the road system is complete with a total of 2.3 miles.

1948 The total cut to March 1948 is 161 M. board feet of sawlogs and 950 cords of extract wood. The cutting, begun in 1947, is a very heavy cut per acre and when it is completed the area will have been commercially clear cut.

Logging Access Road. Drainage Area No. 10.
A Major Source of Turbidity.

The present trend is to construct more roads in harvesting woods products. Experiments have shown that these roads result in reduced water quality. Better road construction and maintenance will increase logging efficiency as well as protect water values.

Results

Water samples have been taken from the stream daily. Comparison of the samples with those from an adjacent undisturbed area reveal some striking changes due to logging activity. A summary of stream turbidities from June 10 to September 21, 1946, is as follows:

	Logged Area (Parts per million)	Control Area (Parts per million)
Average turbidity	94	4
Most frequent value	36	2
Maximum value	3500	80

Since the above summary, a maximum turbidity of 6000 p.p.m. has been measured on the logging area and 120 on the control. The important point is that the water from the logging area is always turbid and never meets the standard of 10 p.p.m. set for drinking water.

Observation indicates that erosion and the associated turbidity are mainly due to poor road building and maintenance, and that improved practices which would reduce it would also save the operator money in the long run. As with so many other things in conservation, good practices which prevent erosion also prove out to be cheaper.

The full effect of the logging upon stream flow has not been completely analyzed. There are indications that runoff from the roads has caused some increase to peak runoff.

Future Plans

The study will continue to measure the extent of water-quality impairment caused by logging, and will measure also the length of time this condition persists after logging is completed. The actual cutting will be finished by December 1948.

A STUDY OF FOREST FIRE IN RELATION TO WATER - AREA NO. 1

Purpose

Uncontrolled forest fires have been proven to be disastrous to timber values in the southern Appalachians but much remains to be learned of their effect upon water values. One of the Coweeta watersheds was burned as a preliminary orientation study in this field.

Description of Area

Size - 38.8 acres.

Elevation - 2300 to 3200 feet.

Stream gaging - A 90° V-notch weir was installed in August 1934.

Land Use History and Vegetation

This watershed has never been cleared but was cut over in 1908, and between that time and 1933 much of the timber was cut for hewn ties. Oak-hickory type is on 77 percent of the area, pitch pine on 12 percent, and cove hardwoods 11 percent.

Treatment Records

A fire line was cleared around the boundary and the area burned over on April 14, 1942. Weather was very dry during and preceding the burning, so the fire was very hot. Eighty-three percent of the 15,030 pounds per acre of litter was consumed in the fire, which covered the entire area. Trees less than 4 inches in diameter were killed, as were branches less than 14 feet high. Larger trees suffered considerable damage when sizeable areas of the cambium layer were killed.

Results on Stream Flow

Stream flow was not affected by the fire. Apparent reasons for this are: (1) As is normal in the spring, the soil itself under the litter was very moist, and consequently the fire had little effect on soil structure or biological activity within the soil. (2) New leaf growth and sprouting occurred to help protect the soil from rainfall impact before hard storms occurred. Considerable herbaceous growth also appeared soon after the burn.

It is obvious, from the reduction in organic material and damage to the forest, that repeated fires would have an undesirable effect on soil structure and create unfavorable conditions for water infiltration and storage.

Future Plans

To compare the effects of repeated fires and of fires at different seasons of the year on water resources, we are now considering further studies on a plot basis. After the full effects of the first burn have been obtained on Area 1, a cycle of burning will be tested on the watershed.

STUDIES TO DETERMINE THE USE OF WATER BY VEGETATION

Purpose

Vegetation, and particularly forest vegetation, uses water for its growth, and at the same time creates a porous soil which admits and stores large quantities of water. These two facts have caused a great deal of speculation as to the role of forests in water conservation and control. Some authorities have advocated clearing of forest land to eliminate the water transpired by vegetation, while others have pointed out that with the forest gone, water would rush off over the soil surface as a flood, adding little to the stored moisture to sustain dry weather stream flow. There is truth in both these extremes, and the job of the watershed manager is to reach an effective compromise between them. In areas where maximum yields of water are important, the task is to reduce vegetation enough to minimize transpiration but to leave enough to maintain and improve the soil. Where the need is to provide the maximum storage in the soil for flood-producing rains, the answer may be to encourage dense vegetation which will make maximum use of soil moisture.

Many problems remain to be solved before there is adequate scientific knowledge to answer all the questions. There is a great need for factual information as to the effect of changes in vegetation upon water yields. To obtain some of this information, drastic cover changes have been made on three Coweeta watersheds.

In two watersheds all tree and shrub vegetation was cut back to the ground with as little disturbance to the forest floor as possible. Trees were left where they fell and no material was removed from the area. Tops and limbs were lopped to lie close to the ground and scattered uniformly over the soil-surface to form a loose mulch. This protected the soil, maintained infiltration capacity, and prevented excessive drying by sun and wind. Sprout growth has been cut back on one watershed (Area 17) to maintain a minimum plant cover, while on the other (Area 13), natural regrowth has been allowed.

On a third area (Area 6) only the vegetation in a narrow strip along the stream channel was cut. The aim here was to cut only those with their "feet in the water," as these trees may be expected to be the most extravagant users of water.

A Study of the Effects of Slashing All Vegetation,

With Natural Regrowth Cut Back - Area No. 17

Description of Area

Size of watershed - 32.8 acres.

Elevation - 2422 to 3381.

Stream gaging - 90° V-notch weir installed June 6, 1936.

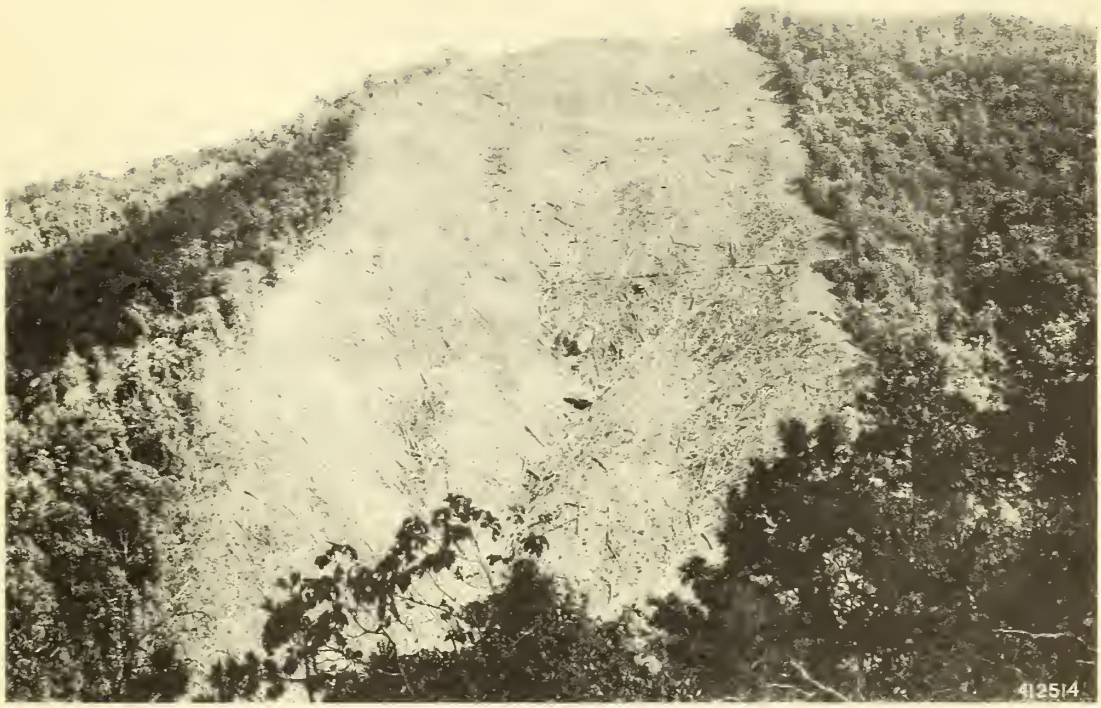
Meteorological Station - Class A evaporation station installed in June 1941. Another station to serve as a check was installed at the same time in an adjacent forested area.

Land Use History and Vegetation

This watershed had never been cleared for agriculture. It had been severely burned over about 1830. No logging had been done, but a few trees were cut for tanbark in 1917. When treatment began, the oak-hickory type was dominant on 93 percent of the area, with cove hardwoods on the remaining 7 percent. Rhododendron and mountain laurel formed a dense understory on 60 percent of the area.

Treatment Record

1941	Jan. 6 to March 31, 1941 - all vegetation cut. Aug. 4 to Sept. 3, 1941 - sprout growth cut back.
1942	June 15 to July 25, 1942 - sprouts cut back.
1943-45	Sprouts allowed to grow undisturbed during war period.
1946	From February to July a part of the sprouts below gage trail cut. Sprout growth cut on entire area Nov. 13 to Jan. 9, 1947.
1947	June 24 to August 22 - all sprout growth cut back.



After Sprout Cutting. Drainage Area No. 17.

By reducing the transpiration to a minimum, and at the same time maintaining a forest soil, an increase in stream flow is obtained.

Results

In the first year after cutting, runoff was increased 65 percent, or 17 area inches. Storm flow was not increased, because no change in infiltration was caused and outflow is still from ground water. The largest increases occur during the late summer and fall. In the first year the increased runoff from August through October was 100 percent. Even with regrowth of vegetation during the war period, the increases persisted, although smaller in amount. No change in water quality took place and the stream has been as clear since treatment as it was before.

Future Plans

Sprouting will be continued for 3 to 5 more seasons. During this time future methods of handling the area will be worked out. The intention at present is to plant white pine at the end of the sprouting period. As the pine stand develops, a comparison can be made of transpiration rate of that stand with the coppice hardwood stand growing on Area 13.

A Study of the Effects of Slashing All Vegetation, With Natural Regrowth Allowed - Area No. 13

Description of Area

Size of watershed - 39.8 acres.

Elevation - 2349 to 2965 feet.

Stream gaging - 90° V-notch installed March 12, 1936.
Replaced by 120° V-notch on Sept. 21, 1939.

Meteorological Station - Class A evaporation station operated in this area and adjacent check area from May 1940 to June 1942.

Ground-water wells - Three wells dug in 1939 and 9 others added in 1941. Five are equipped with recording instruments.

Land Use History and Vegetation

Before treatment the stand was composed of vigorous second growth about 40 years old with old-growth pitch pine-hardwoods on the upper slopes and ridges. A small clearing was made in 1896 in the bottoms but was abandoned before 1900. Oak-hickory type occupied 70 percent of the area, cove hardwoods 10 percent, and pine-hardwoods 20 percent.

Treatment

All woody vegetation was cut between November 1939 and 1940. Nothing has been done since that time; regrowth has been vigorous and sprouts are 20-30 feet in height at present.

Results

The first year after cutting, water yield was increased 16.4 inches in the same manner as on Watershed No. 17. After eight seasons of regrowth, water yield is still about 15-20 percent higher than before cutting but shows a steady decrease with the growth of trees. Results from this area will be compared with those from Area 17, where sprouts are kept down to estimate the year-by-year water use of the new stand.

Future Plans

The new growth will be allowed to develop to furnish information about transpiration use of stands of increasing age.

A Study of the Effects of Cutting of a Strip Along the Water Course - Area No. 6

Description of Area

Size of watershed - 21.9 acres.

Elevation - 2282 to 2955 feet.

Stream gaging - A 90° V-notch weir was installed July 1934.

Ground-water well - A recording well has been operated since September 1936.

Land Use History and Vegetation

No clearing had been done for agriculture. A sawmill operated near this area in 1912, and during its operation the stand was heavily culled. Oak-hickory type is on 88 percent of the area and cove hardwoods on 12 percent. A dense understory of rhododendron is present.

Treatment

All woody vegetation less than 15 feet above the stream bed was cut in the same way as on Areas 13 and 17. This cutting was made on July 21-25, 1941. The area so cut was 2.6 acres, or 12 percent of the area. The strip cut was 1600 feet long with a width of from 60 to 250 feet.

Results

Preliminary analysis indicates that daily runoff during the first summer was increased from 4 to 20 percent and averaged about 12 percent for a 10-day period. This increase was due to the almost complete elimination of the normal summer diurnal fluctuation of stream flow caused by transpiration draft.

Future Plans

When analysis of present experiment is completed, it would be desirable to cut back sprouts on the present strip and widen it to determine whether additional increases can be obtained in the same proportion to previous area cut.

SUMMARY OF WATERSHED TREATMENTS

The results from watershed treatments prove how great an effect man has upon water resources. When we create unfavorable soil conditions such as on the mountain farming area, surface runoff will occur, washing away the soil and causing high flood peaks. Careless logging methods will cause the stream to be too muddy for use. However, by modifying the density of vegetation without disturbing the soil, we can increase the amount of water suitable for our uses. There are a great many questions yet to be answered and many of them can and will be worked out here on a watershed basis. The real contribution of these experiments to date is that they illustrate for the first time on a watershed basis that man does have the power to act constructively, as well as destructively, upon the water resources available to him.

BASIC HYDROLOGIC RESEARCH

As distinguished from applied hydrology, considerable work in fundamental hydrology has been carried on at Coweeta for the purpose of clarifying a number of basic concepts and establishing a sounder basis for understanding forest-streamflow relations. Rainfall, soil, and topographic conditions particularly suitable for watershed studies have facilitated several important research findings in a shorter time than had been anticipated.

Channel Precipitation

The general shape of storm hydrographs from undisturbed forest areas during short intense storms resembles the shape of hydrographs produced by surface or overland storm runoff from relatively impervious land surfaces. Hydrologists interpreted this as meaning that there was inadequate infiltration of rainfall into the forest soil that resulted in surface storm runoff. Results of the Station's early studies showed that rapid rises in streams from forested areas are due almost entirely to outflow from rain that has fallen directly into the stream channel and are not due to lack of infiltration into the forest soil. By establishing the exact contributions of channel precipitation to runoff on a watershed basis, it was possible to clarify a misinterpretation that was one of the obstacles to the mutual understanding of forest-streamflow relations.

Subsurface Storm Flow

At the same time it was also observed that considerable increase in stream flow not accountable for as channel precipitation does take place from undisturbed forest areas during long continued rains. By studying a large number of hydrographs from different experimental watersheds on the Coweeta Forest, it was found that the increase in storm water was due to both channel precipitation and to a form of subsurface storm flow, the nature of which had never been clearly demonstrated previously. Movements of the water table as recorded in observation wells were employed to establish the fact that the rainfall first entered the soil and then moved laterally through the porous upper soil layers to the stream channels in time to contribute to the storm runoff. The runoff was thus shown to be intermediate between overland storm flow and ground-water seepage from the underground storage usually supplying the normal flow of streams during non-storm periods.

The above researches furnish a basis for a more realistic interpretation of forest-streamflow relations in terms of watershed storage than was possible before experimental data became available. They made it possible to explain stream behavior through the separation of stream flow on the basis of the source of the water: (1) from channel precipitation and overland storm runoff, (2) from temporary subsurface detention, and (3) from more permanent ground-water storage. This separation is necessary for interpreting the effect of different land use practices on stream behavior, or for comparing the effects of watershed treatments.

Annual Water Balance

Of special significance from the standpoint of fundamental hydrology are the findings of the Station relating to the annual balanced water economy of small watersheds. These findings substantiate the theory that in humid climates precipitation recharge of a watershed for any one year should tend to equal the discharge from the watershed as runoff, transpiration, and evaporation, together with changes in the amounts of soil moisture and ground water stored on the watershed. Data for the substantiation of this theory as a sound hypothesis were published as a part of the Station's regular watershed studies.

In watershed management research we are finding out how foresters and land managers can best discharge their responsibilities as custodians of water resources. Water has a commanding place in the economy of forest land. For many sections, the local commodity value of water far exceeds the total value of harvested timber and other wood products. The southern mountain region is the source of water supplies essential to the greatest aluminum and textile industries in the world. An expanding paper and rayon industry is continually looking for additional water supplies. Municipal expansion has already led to rivalry for watershed areas. Hydroelectric power developments rank among the foremost of the Nation. Sportsmen from the great population centers of the East are making increasing and more exacting demands on the streams for recreational uses.

Notwithstanding their importance in the economy of the region, the watersheds of the southern mountains have suffered much from mismanagement, from indiscriminate cutting and burning, from soil depleting types of mountain agriculture, and grazing. There has been a progressive deterioration of water resources as a result of land exploitation over a period of more than a century. Reduced water quality is evident in the sediment and pollution now carried by the streams. Decreased water supply is evident in more irregular stream flow and in the diminution of ground-water reserves. Floods are of frequent occurrence, with losses to crops and livestock and destruction of fertile valley land. Stream channel control is becoming increasingly necessary to prevent the cutting away of valuable land, loss of roads and bridges, and the debouchment of rubble debris into the valley land below.

The ultimate goal of the Station's watershed research program is to discover and establish a sound and practical basis for the management of forest land in the interest of water resources. Although the relative importance of specific problems may not be the same for different sections of the Station's territory, research problems in water resource management all relate directly to the use of land. Practical application of research findings will come about through improvement or change in land use practices. Hence the real problem in water resource management is to determine and understand the relation of different land use practices to water, and ultimately to apply this knowledge to land management designed to restore and maintain favorable water supplies. As the facts of forest-streamflow relations become better known, they will be integrated into a forest management program directed toward the maximum utilization of all forest resources. In this integrated picture the utilization of one forest product will be carried out without jeopardy to other forest products. What we are finding out about water on the Coweeta Forest will expedite this broad approach to practical forest management.

WATER UNITS

1 cubic foot = 7.4805 gallons

1 acre foot = 43,560 cubic feet

1 acre foot = 325,851 gallons

1 acre inch = 3,630 cubic feet

1 acre inch = 27,154 gallons

1 cubic foot per second = 646,317 gallons per day

1 gallon per minute = 1,440 gallons per day

1 million gallons per day = 1.5472 cubic feet per second

WATER REQUIREMENTS

Municipality - 150 to 200 gallons per capita per day

Paper pulp (1 ton dry) - 60,000 to 90,000 gallons

Textile mercerizing (1,000 lbs. processed) - 30,000 gallons